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During the period July 1997 – June 1998 work has continued according to the proposed plan. Advances in research have been made in the following areas:

- The design and implementation of the first-ever ARAM in the CNN Chip Set Architecture was successfully competed, and the samples were successfully tested;
- A major theoretical breakthrough has been achieved: it was shown that the genesis of complexity lies in the local activity of the cells and local interactions of the Cllular Nonlinear Networks;
- Several CNN templates and subroutine designs, including mathematical morphology, have been developed and used in various applications;
- Advances in application of CNN have been made in the area of condition-based maintenance and image fusion.

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PROGRESS REPORT

for the period July 1997 -June 1998, on

Nonlinear Circuits and Neural Networks: Chip Implementation and Applications of the TeraOPS CNN Dynamic Array Supercomputer

Grant No. N00014-98-1-0052

1996-1998

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Summary

During the period July 1997 - June 1998, our work has been continued according to the proposed plan. Advances in research have been made in the following areas:

- The design and implementation of the first-ever ARAM in the CNN Chip Set Architecture was successfully competed, the samples were successfully tested;
- A major theoretical breakthrough has been achieved: it was shown that the genesis of complexity lies in the local activity of the cells and local interactions of the Cellular Nonlinear Networks; in addition
- Several CNN templates and subroutine designs, including mathematical morphology, have been developed and used in various applications;
- Advances in application of CNN have been made in the area of condition based maintenance and image fusion.

Task 1: *The design and implementation of the first-ever ARAM in the CNN Chip Set Architecture, measurements of the operational CNN Universal Chips*

An analog random-access memory chip (ARAM) in a 32x256 configuration has been designed and fabricated through the MOSIS service using Hewlett-Packard's 0.5-micron CMOS technology. The main parameters of the ARAM chip are as follows:

- 637 analog memory cells/mm2,
- 7-8 bits of accuracy,
- 10 MS/sec input rate1MS/sec output rate,
- 80-100 msec storage time.

The innovative circuit design solutions provide for robust operation. A series of electrical tests at our laboratory in Berkeley confirmed the design goals. Functional tests executed in Budapest in the framework of an ONR - NICOP grant, showed that the

specified accuracy is enough to produce practically distortionless images when viewed by a human observer.

Task 2: *The local activity principle*

Complex systems that consist of a very large number of nonlinear dynamical systems distributed in space and having local interconnections, exhibit emergent, self-organizing, and sometimes exotic properties in space and time. Although these truly interdisciplinary phenomena have been widely studied and described, no solid and rigourous conditions have been established for explaining the genesis of these systems and why they exhibit the surprising or strange phenomena.

It has been shown that the principle of local activity is the key to explaining these unusual properties. In addition, analytical tools have been developed to determine the parameter ranges for exploiting the local activity conditions and to construct useful systems.

Task 3: *Design of new templates and subroutines, including mathematical morphology*

Innovative applications, like condition based maintenance and image fusion, need new templates and subroutines, especially for the spatial-temporal kind of processing where CNN technology truly excels. Mathematical-morphology based tools are very attractive for the algorithm designer and provide a powerful tool for solving a large set of difficult problems. Their implementation, however, in classical computers is inefficient. CNN computing technology provides for a natural platform for mathematical morphology. Several templates and subroutines have been developed and used in the applications described below. An important result is the implementation of a wave-type metric.

Task 4. *Application case studies.*

Condition based maintenance for detecting the start of deterioration in helicopter engines is an ambitious task for today's technology. Teaming up with Dr. Abe Schultz at the Naval Research Laboratory, we have developed analogic CNN algorithms to solve both the basic image preprocessing and also the subsequent classification task to detect debrie particles in the high-speed oil flow of a helicopter gear-box. A major difficulty in solving this problem is the presence of a large number of air bubbles in the flow.

Preprocessing algorithms have also been developed for image fusion.

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